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TRENDS IN EXPLORATION OF MINERAL DEPOSITS

BY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

TRENDS IN EXPLORATION OF MINERAL DEPOSITS[1]

By Lowell B. Moon[2]

Regardless of how a mineral deposit is first discovered or by whom, any mining enterprise based upon it must pass through a preliminary stage of exploration. The common understanding of "exploration" among mining engineers is well-expressed by Jackson and Knaebel:[3]

> Exploration work ranges from that performed by the individual prospector employing only the simplest tools and equipment to elaborate campaigns involving the expenditure of large sums of money and the use of churn- or diamond-drilling equipment, large test-pitting crews, or sometimes a regular mining organization. In any event, the object is to determine as accurately as possible, with the funds available, the size, shape, and other physical characteristics of the ore bodies and their average value or grade.

The mining engineer, in his exploration of a deposit, is primarily concerned with "putting a pick in the ground" to determine the economic possibilities of the deposit. He is concerned with actually seeing and testing representative parts of the deposit, with determining the grade of the ore and how it can be treated, with delimiting the minable part of the deposit and calculating its tonnage, with finding how well the walls of the deposit will stand and how much water will have to be handled during the mining, and with interpreting what he sees and finds from his tests. In his interpretation he is concerned with answering the questions: "How much of the deposit can be mined?" "By what method can it best be mined?" "How can the ore be treated?" "Where can the product be marketed?" All these questions, of course, actually resolve into one: "Can a mining enterprise be based on the deposit?"

1/ The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7312."

2/ Chief, Mining Branch, Bureau of Mines.

3/ Jackson, C. F., and Knaebel, J. B., Sampling and Estimation of Ore Deposits: Bureau of Mines Bull. 356, 1934, p. 3

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Many methods have been devised for "putting a pick in the ground" to explore mineral deposits. During the last 5 years the Bureau of Mines has utilized most of the available tools.

The development of dirt-moving equipment has made it possible to remove overburden at low cost. It has become axiomatic in the Bureau that in most cases it is wise to explore first the "zero level" of deposits that come to the surface. The bulldozer has proved to be one of the most useful tools in surface work, although dragline scrapers, stump pullers, and several types of power shovels have their places. The particular advantage of the bulldozer is its versatility. It is useful not only in exposing the "zero level" of the deposit but also in the auxiliary heavy work that accompanies most exploration. At one Bureau of Mines project it was used to trench through clayey overburden as much as 20 feet thick, to clear brush, to uproot and remove trees, to build roads, to transport large samples, to clear out an old open pit preparatory to sampling, to move a truck-mounted churn drill when mud or snow prevented self-propulsion, to prepare drill sites, and to clear snow from roads.

The reason for development of the "zero level" is to establish the trend and extent of the deposit in two dimensions and to expose the top of the ore body so that it can be sampled. Once the trend of a deposit has been established, trenching can be done systematically to permit representative sampling. A wide deposit is most effectively exposed for sampling by regularly spaced, parallel, crosscut trenches. A long, narrow deposit can often be exposed along its entire strike length.

If results of sampling the "zero level" warrant exploration in the third dimension, or if the deposit does not occur close to the surface, some form of deeper probing is necessary. Where surface indications are so good that there is no doubt the deposit will be mined, or where the values are so irregularly distributed that only tonnage samples will be representative, "man-size" openings such as test pits, shafts, adits, drifts and crosscuts usually follow surface exploration. If quick, comparatively cheap information in the third dimension is needed, some sort of drilling usually precedes exploration by "man-size" openings. A deposit in which the values are regularly distributed so that representative samples can be obtained in small openings may be explored entirely by drilling. A large deposit close enough to the surface to be mined by open pit usually is explored by drilling because larger, more costly openings would be of no value later during the mining operation. If the deposit occurs at great depth, the quickest and cheapest method of exploration is by drilling.

The advantages and disadvantages of the several usual types of drills are commonly known. The churn drill is widely used in many types of deposits. The diamond core drill is probably the most generally useful in "hard-rock" deposits and is, of course, particularly valuable where angle holes are needed.

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The bucket-drill or "California cesspool digger" was first used to explore a mineral deposit in the dry placers at Atolia, Calif.4/ It makes a bore 12 to 30 inches in diameter. The Bureau of Mines has found it of great value in obtaining large samples of shallow deposits of material that is comparatively soft but that stands well. It was very effective to a depth of 120 feet in the Batesville (Ark.) manganese deposits, even though occasional boulders had to be blasted, and in the Coso (Calif) mercury deposits, even though hard layers of opalite were encountered.

The truck-mounted "seismograph" drill has proved to give excellent "undisturbed" samples of bauxite and clay. It is especially well adapted to penetrating thick, bouldery overburden. A power auger mounted on a trailer has been used effectively in drilling through boulder-free overburden and sampling underlying bauxite in Alabama.5/ The samples are somewhat contaminated by being lifted through the overburden, but the cheapness and speed in shallow deposits are remarkable.

In drilling and sampling a deposit of soluble salts in Utah, the Bureau of Mines,6/ used a standard oil-well rotary rig. To minimize solution of the salts that were cored, a drilling mud containing the same salts in solution was used. A wire-line core barrel was used in coring the salts. With this apparatus a core could be taken from a depth of 3,000 feet in 15 minutes instead of the 3 or 4 hours that would have been consumed with the more common core barrel requiring removal of all the drill pipe each time core is pulled. From the point of view of securing a good sample, the wire-line core barrel had the further advantage of keeping the highly soluble salts in contact with the mud solution in the hole for only a brief time.

Dupuy has described a novel method of sampling a gold deposit in dry ground,7/ without the usual "slugging of values" caused by concentration of the gold at the bottom of the hole when wet churn or diamond drills are used. A pneumatic wagon drill was used dry in conjunction with a vacuum sample collector. Vertical holes as deep as 150 feet were drilled and successfully sampled by this method.

Exploration of a deposit by drilling is primarily to determine whether a mining enterprise can be based on it. The samples extracted and the information obtained from them are the objective, not the holes. Drill holes should be placed on a regular pattern in order that the samples obtained will be representative of the deposit. They should crosscut the deposit as nearly as possible at right angles. The objective of obtaining all possible information should be kept in mind at all times,

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4/ Frommel, H. W. C., Sampling and Testing of a Gold-Scheelite Placer Deposit in the Mojave Desert, Kern and San Bernardino Counties, Calif.: Bureau of Mines Inf. Circ. 6960, 1937, 18 pp.

5/ Dupuy, Leon W., Power-Driven Auger Drill Cuts Exploration Costs: Eng. and Min. Jour., vol. 145, December, 1944, pp. 98 and 99.

6/ Bureau of Mines, "Thompson Magnesium Well, Grand County, Utah: War Minerals Rep. 12, 1942, 39 pp.

7/ Dupuy, Leon W., Sampling the Picacho with Drill and Vacuum Collector: Eng. and Min. Jour, vol. 141, 1940, pp. 29-31.

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even though the holes consequently progress more slowly. Most of these precautions are axiomatic, but operators tend to make a record for speed at the expense of the accuracy of the information obtained.

Time and money may sometimes be saved by a combination of "man-size" underground openings and diamond drilling. A shaft or a crosscut will often provide a new base of operations from which holes may be fanned to penetrate parts of a deposit that would otherwise be accessible only by long holes that would intersect the deposit at oblique angles.

In some cases enough information will be derived from drilling to permit development and mining to proceed without further exploration of the deposit. This applies particularly where the treatment method is established and where mining is to be by open pit. If the treatment method is not established, a necessary part of the exploration of the deposit is to take bulk samples representative of the ore and to determine in the laboratory or pilot plant how the ore can be beneficiated. If the deposit is to be mined by underground methods and there is any doubt as to the strength of the walls or the volume of water that must be handled, or if the grade of ore is not sufficiently well established, drilling should be followed by "man-size" underground exploration that will provide the lacking information. It may be desirable to mine some of the ore experimentally to see how the walls stand.

There is no best method of exploring all mineral deposits, but there is usually a best method or combination of methods to explore any given deposit. Although it may seem paradoxical, the same factors of size, shape, attitude, hardness, water content, character of wall rock, and distribution of values that are to be determined by exploration are those that guide the selection of method. A thorough preliminary examination by an engineer cognizant of the problems to be solved and familiar with the methods and equipment available will point the way to the most expeditious procedure.

As the higher-grade and more easily accessible deposits are depleted, two trends in mining, and consequently in exploration, are developing. The first is the result of the necessity to gather up the comparatively high-grade "crumbs" of ore left in small and out-of-the-way deposits. The second is toward exploration and utilization of large but lower-grade or more deeply situated deposits.

Because the stakes are small, few deposits in the first category will be able to stand the expense of elaborate exploration campaigns. The decision of whether they are worth exploiting will be made on the basis of surface exploration, with a minimum of preliminary third dimensional information. If considerable exploration of this type is undertaken, many ingenious combinations of portable equipment may be developed. A four-wheel drive truck similar to some of the present army equipment could have mounted on it a small compressor and a winch that could be used for hoisting or run a drag-line scraper for trenching. The scraper could also be used for mucking exploratory adits or inclines. In country requiring much trail building, another type of outfit could be built around a tractor as the

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prime mover. The tractor would, of course, be equipped with a bulldozer blade. A compressor winch, even a small diamond drill for obtaining third dimensional information, could be mounted on a trailer that would be pulled by the tractor. A power take-off would permit running a small crusher, perhaps some simple washing equipment. It seems unlikely that exploration of the small, inaccessible deposits will become much more refined than at present. More portable equipment will be available, however, and may be combined into compact, general-purpose outfits that would be useful for whatever type of exploration might be required. Such outfits could perhaps be pressed into service to mine out small deposits. If attended by an auxiliary "jeep" for transportation of fuel and supplies, they would be quite versatile.

As lower-grade or deeper deposits are considered for exploitation, mining costs per unit of valuable mineral will rise, and the margin of profit will become slimmer, assuming constant prices. In dealing with deposits whose chance for exploitation depends upon a large capital outlay, skillful management, and recovery of low values, where the possible margin of profit is very small, the maximum amount of preliminary information will be required. Not only will the amount of exploration be increased, but the ultimate in information will be obtained from the openings made and from the samples taken. Particularly for deep underground mines, faults and fissures in the wall rock near the deposit will assume added importance in determining the feasibility of mining. In deeper mines the strength and elasticity of the wall rock may control its supportability to some extent. These and other measurable physical properties may influence the drillability and breaking qualities of the rock and of the ore. The Bureau of Mines has begun a series of tests on drill cores from operating mines to determine strength, elasticity, abrasiveness, and other physical properties and to correlate them if possible with mining methods that are in use or could possibly be used. If such correlations could be established, the information obtainable from drill cores would be increased considerably.

Although there will undoubtedly be many refinements in equipment for making "man-size" and drill-hole openings for the exploration of mineral deposits, the fundamental types of equipment now in use probably will continue to be employed for a long time. A greater advance may be made in the amount of information gleaned from the openings.

This is not the place to discuss geophysical methods, but as more sensitive, accurate methods are developed, drilling holes to determine the size, shape and exact location of mineral deposits may be minimized. Geophysics probably will be used as another tool in the exploration of deposits in addition to its present role in the exploration for deposits. Drill holes and other openings for extracting samples will continue to be needed, but the targets may be more precisely determined in advance.

As the geophysicists acquire added skills in detecting "blind" deposits, it will be necessary to hit comparatively small targets at greater depth with drills. Much is known about anticipating and controlling the direction and inclination of drill holes, but more will be learned. Further advances will be made in the surveying of drill holes.

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To make possible the exploitation of the "crumbs" of higher-grade and large but lower-grade or deeper deposits, it will be necessary for the engineer in charge of exploration to consider other things besides the techniques of making openings and of obtaining information from the samples. All possible advantages in local markets will have to be investigated. It cannot be considered as necessarily fixed that the concentrate specifications of a distant, existing reduction plant must be met. The existing industries based on domestic raw materials did not develop as a result of trying to supply a foreign market. The copper industry in the United States would not have developed if we had continued to ship western ore to Swansea, Wales, as was done in the early days. Because of the present size and solidarity of certain parts of the mineral industry, we are prone to consider that the only chance of successful exploitation of a mineral deposit is to supply a product that meets fixed specifications. We forget that those specifications were originally fixed to meet the characteristics of available raw materials. Because the product of a deposit cannot meet the fixed specifications is not sufficient reason to give up. Combining a mineral with complementary industrial raw materials as close as possible to its source should be considered. If a market for the product that would result does not exist, perhaps one can be created.

The stone age man who first smelted iron ore probably did not do it to satisfy an existing need. It is likely that after he had accidentally obtained the iron he thought of a way to use it.

Mining is, of course, only one part of the mineral industry pattern but it deals with the only part of the pattern that is necessarily fixed, the mineral raw materials. Fixed, not in the sense that we must continue to use the same raw materials, but fixed in the sense that we cannot change the manner in which they occur in nature. All the techniques of mining, ore dressing, metallurgy, and fabrication, as well as the uses for the final products, are man-made and can be changed and improved. Most of the minerals mined will continue to be used in the established pattern but the possibility of locally altering the pattern to fit available raw materials should not be overlooked.

When a deposit has been explored, when the engineer has found out what he can about it with a reasonable expenditure, he is in the same situation as the stone age man with the piece of iron. His job is to find a use for it.

As stated in the beginning, the purpose of exploration of a mineral deposit is to answer the question: "Can a mining enterprise be based on the deposit?" If the answer is to be "Yes" in the future, the techniques of making openings and particularly of gleaning information from samples taken must be improved. In addition, every possible technologic and marketing advantage must be sought, and seeking for it must be considered an essential part of the exploration.

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